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APPLICATION OF LIGHT AND IMAGE INTENSIFICATION

by

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[illegible] development of low resolution sandwich type image intensifiers and high resolution image intensifiers with improved photo[illegible] and electroluminescent films.

SUMMARY

Results of measurements described in the previous Report are discussed. Hall effect measurements were made, and experiments for eliminating the inhomogeneities on the image intensifier panel ~~have been~~ were started. Work on evaporated EL films ~~has been~~ was started.

I DISCUSSION OF PC CHARACTERISTICS

Three sintered CdSe PC cells in both coplanar and sandwich construction were studied, ~~as described in the previous Report (No. 2).~~ Currents as a function of the applied voltage with the illumination as parameter were recorded, and decay and rise time-constant measurements at different light intensities were made. From these measurements and the geometrical data of the cells, fundamental semiconductor characteristics were calculated, as described in Table 1 and Table 2 of Report No. 2. The numerical data for one of the cells is given in Table 3 of the same Report. The discussion of these data follows here. Numerical [illegible] results is discussed.

Examination of Figures 1 and 2 and of the corresponding numerical data in Table 3* shows a large difference between the characteristics of coplanar and sandwich construction (surface and volume currents) of the same material. While the coplanar cell has high dark current and nearly linear current vs. voltage relation (ohmic electrodes), the sandwich cell shows linearity only below 10 volts, and becomes highly superlinear above 50 volts when the top electrode is positive. When the top electrode is negative this superlinearity starts at lower voltages. In both cases (top + and -) the superlinearity becomes evident at lower voltages when the illumination is lower. Considering the field strength, for both the coplanar and sandwich constructions, one calculates a field strength of 1.33 x 10^3 volts/cm with 100 volts on the coplanar cell. The same field strength is reached with 11.6 volts on the sandwich cell. Therefore, measurements with higher field strengths on the coplanar cell should be made for seeing if a superlinearity exists there as well. It is true that the electrodes in the two cases are somewhat different. In the coplanar cell both electrodes are tin-oxide while

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* Figures and Tables refer to those in Monthly Technical Engineering Report No. 2

In the sandwich cell the bottom electrode is tin oxide and the top electrode is gold. The tin oxide electrodes are present during the high temperature baking of the cell, while the gold electrode is evaporated after the sintering.

For comparing the coplanar and sandwich cells, the conductivities must be considered. The data in Table 3 reveal a large difference: more than one hundred times higher conductivity of the coplanar cells than that of the sandwich cells at 1 ft-c illumination and higher factors at lower illuminations. This increasing conductivity ratio at decreasing illumination is caused by sublinearity in the current vs light intensity characteristics that prevails for the coplanar cell and the superlinearity that exists for the sandwich cell.

One tries to explain these variances by the differences between the crystal structure of a surface layer and that of the inside of the material. However, another reason for the difference is the absorption of high energy photons ($\lambda < \lambda_{max}$) in a very thin layer of the CdSe. This does not present any problems for the coplanar cell if the light enters on the electrode side. But if the light enters on the other side the shorter wavelengths are absorbed faster than the longer ones and the spectral response curve is transferred to longer wavelengths (see Figure 20 in Final Report NAVTRADEVCEN 562-). In the case of sandwich construction the current carrier electrons must be transported through the layer from the negative electrode to the positive electrode. There is no complication when the light enters on the negative electrode ("top -" in the measurement); only the excited electrons have to be diffused toward the positive electrode. When the light enters on the positive electrode ("top +" in the measurement), the negative electrode has to supply the electrons. This can happen as is the case in the normal conduction mechanism of the coplanar cell as well. The electron which arrives at the positive electrode is replenished with a new electron emitted from the negative electrode if this electrode has ohmic contact to the PC material. The shift in the spectral response curve (see Figure 3) proves that the excited electrons are primarily responsible for the photo-current.

The increasingly superlinear dark current at increasing field strengths is explained by the space charge limited currents. An inertia phenomena with changing field strength is connected to this mechanism, and both will be studied at a later date.

The decay and rise time constants of the cells were measured at an earlier date. Comparing Figures 4 and 5, one sees that the response time of the sandwich cell is slower than the coplanar cell by a factor of approximately five. The rise time constant is about three times higher than the decay time constant in both cases. In the calculations only the decay time constants were considered.

For the gain-calculation, it was supposed that there are about 10^{13} photons/cm^2 sec in 1 ft-c of light intensity and the quantum efficiency is 1. The curves in Figure 7 show that the gain is higher with higher voltage, reaching 10^4 electrons/photons at 50 V. The positive or negative slope of these curves corresponds to superlinear or sublinear current vs. light intensity characteristics respectively.

The M-factor is connected to the maximum gain available with a PC material. The maximum gain is limited by the field strength where space charge limited currents enter and in this case M is equal or lower than one. In some special cases M can be higher than one representing a PC material with superior characteristics. The M factor of our photocells (Figure 8) show that they are in the general category, where $M < 1$.

For calculating the electron density n_- it was assumed that the mobility is equal 10 cm^2/volt sec. It was assumed furthermore that the absorption and conduction mechanism in the coplanar cell takes place in a thickness of about 10 micron (t^*). In the case of the sandwich cell the current goes through the total thickness. The life time of the carrier, calculated with these assumptions, is acceptable for the sandwich cell, but are in contradiction with decay time constant measurements for the coplanar cell. A larger value than the decay time is obtained which is impossible. To overcome this difficulty one has to assume, at least for the coplanar cell, that the mobility is equal to about 100 cm^2/V sec. It is not unreasonable to suppose that the mobility is higher for the surface currents, than for the volume currents. Data calculated with $u = 100\ cm^2/V$ sec for the coplanar cell, are presented in Table 4.

Figure 9 shows the calculated trap distributions for both types of cells. As is to be expected, the trap distribution is the same for 10 and 50 volts, the trap density is higher for the sandwich "top -" case and the trap distribution is nearly exponential.

III. OTHER EXPERIMENTAL WORK

Some Hall constant measurements were made, but the low signal to noise ratio in the measured Hall-voltage gave too high errors, and the values obtained for the mobility are not dependable. Improvements are being made on the measuring instrument.

Some experiments were made for finding out what is the cause of the grainy structure in the image intensifier panel. CdSe PC layers made with powders (1) ball milled much longer (16 hours) than usual; (2) prebaked much longer (8 hours) than usual. The long ball milling did not seem to improve the homogeneity, but the long prebaking showed some improvement. Experiments will be repeated and continued.

The clean room work is progressing, although it is a little behind schedule.

IV. EVAPORATED EL FILMS

On reactivation of this work, the two main objectives are improvements in maintenance and efficiency. EL powder phosphors containing iodine or gallium as coactivator, rather than chlorine, have been made; these coactivators, when fired into the film from the powder phosphors, are intended to improve maintenance, both with AC and DC excitation. Yellow-emitting films were made, for the first time, from the iodine or gallium containing powder phosphors and these had reasonably good emission for the first trial. No new maintenance data have been obtained yet.

Jigs and a dry-box have been assembled so that both maintenance and efficiency measurements can be made in a dry atmosphere. Efficiency measurements were begun. So far, the AC efficiencies run about 0.2 lumens per watt for the yellow-emitting films (as reported in NAVTRADEVCEN 562-1) which is to be compared to a maximum of about 0.4 lpw for the best yellow-emitting powder phosphors. These AC efficiencies require an insulating layer on the film, and such a layer is also required for best maintenance (see same NTDC report) and probably to prevent cross-contamination when the photoconductive layer is fired on. Therefore, most of the films from now on will be provided with an insulating layer; development of such a layer is regarded as an important aspect of the EL film—PC sandwich, and equipment refinements to do this are already in progress. Real gains in efficiency are also possible through the use of insulating layers. MgF_2 and SiO are being used at present.

Efficiencies of one or two lumens per watt have been observed from green-emitting films, and some work is planned on this type (efficiencies of the equivalent green-emitting powder layers run around 2-3 lpw). However, DC EL is far stronger in the yellow-emitting films and, in addition, very high sensitivity to AC voltage (perhaps 100 ft-L at 30 volts 400cps) has only been observed so far in yellow-emitting films.

Much effort was spent this month in ironing out problems in uniformity of the films, partly brought on by the long period during which no films were made. As much of next month as necessary will be spent on this problem, which is one of visual appearance more than of utility for testing, etc.

V. VISITS AND CONFERENCES

On September 6 a trip was made to the Canadian Westinghouse Company, Hamilton, Ontario, Canada by Z. Szepesi. Specifications for a subcontract on PC powders were discussed.